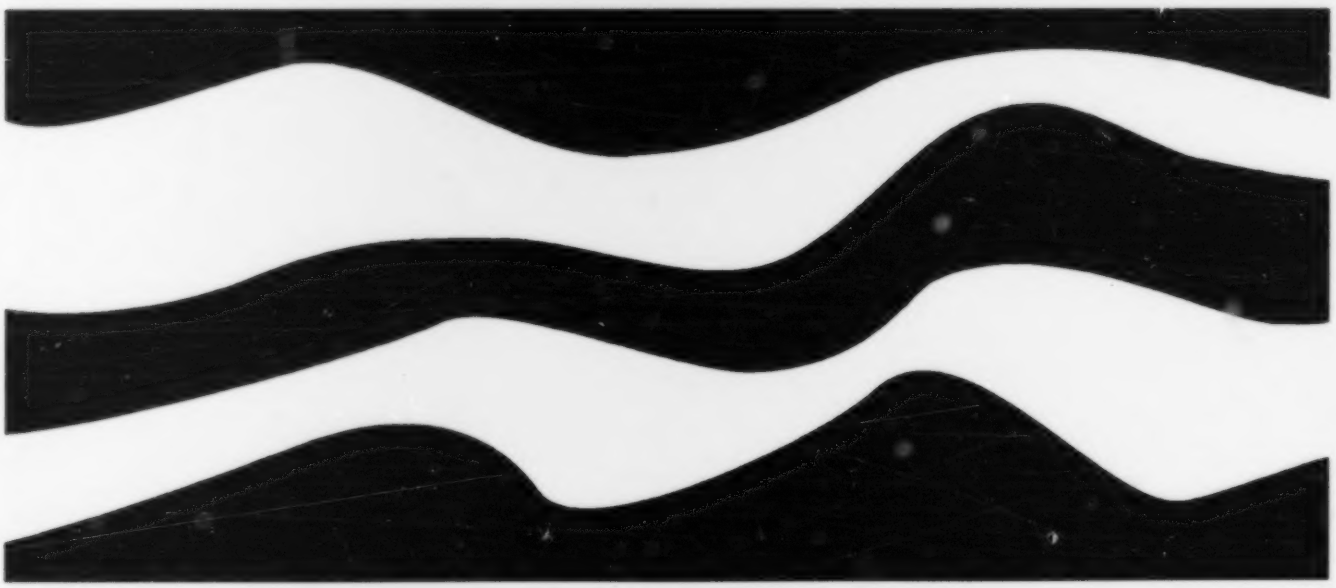
Kelp Inventory, 1995

Nootka Sound

IEC Collaborative Marine Research and Development Ltd.

BRITISH COLUMBIA

Ministry of Fisheries
Sustainable Economic Development Branch



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KELP INVENTORY, 1995
NOOTKASOUND

prepared by

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for

Ministry of Fisheries

and

Nuu-Chah-Nulth Tribal Council

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ABSTRACT

A modification of the Kelp Inventory Method (KIM-1) developed by Foreman (1975) was used to estimate the total standing crop biomass and kelp bed area of *Nereocystis luetkeana* and *Macrocystis integrifolia* along portions of the southwest shore of Nootka Island, the west and south shores of Hesquiat Peninsula and a section of Hesquiat Harbour for July 29, 1995. Results indicated that 9,611 tonnes of *N. luetkeana*, 55,284 tonnes of *M. integrifolia* and 8,941 tonnes of *N. luetkeana* and *M. integrifolia* in mixed beds were present. Total bed surface areas of *N. luetkeana*, *M. integrifolia* and mixed beds were estimated to be 213.7, 518.1 and 117.8 hectares, respectively. Five charts are presented which show the position, extent, species, and density of every discernible kelp bed within the survey area. For management purposes the area is divided into numbered, kilometre wide blocks.

Portions of the inventory area are compared with overlapping areas from a 1975 survey that used the KIM-1 method.

ACKNOWLEDGMENTS

This project was inspired by Sennen Charleson of the Hesquiaht Band. The success of the inventory was due to the efforts of the following people: Michael Coon, Christine Hodgson and Barron Carswell of the Ministry of Agriculture, Fisheries and Food; Jim Lane of the Nuu-chah-nulth Tribal Council; Dave Ignace and Paul Lucas of the Hesquiaht First Nation; Larry Baird Jr. of the Ucluelet First Nation; and Charlie Coots Jr. of the Uchuchlesaht First Nation, who carried out the field work. Christine Hodgson and Jim Lane deserve special acknowledgement for organizing the field work. Michael Coon, Christine Hodgson and Barron Carswell also coordinated the various aspects of the project. Daniel Tresa and Erle Dzus of McElhanney Consulting Services Ltd. provided computer mapping services. North West Geomatics Ltd. provided aerial photographic coverage of the area. Kathy Evans of the Ministry of Agriculture, Fisheries and Food provided licensing statistics and information on kelp use in British Columbia. Mr. Bodo R. de Lange Boom, tides and currents analyst at the Canadian Hydrographic Service, provided tidal height data for the inventory area.

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INTRODUCTION

Nereocystis luetkeana (Mertens) Postels and Ruprecht and *Macrocystis integrifolia* Bory form beds along extensive portions of the British Columbia coast. In 1975 the Provincial Government undertook a program to locate and quantify the standing crop of these economically important kelps using the inventory method (KIM-1) developed by Foreman (1975). Since that time major kelp stocks have been inventoried throughout the province (Coon, 1981; Coon et al., 1976, 1979, 1980, 1981, 1982; Field, 1996; Field et al., 1975, 1977, 1978; Sutherland, 1989, 1990).

The present report contains the results of a 1995 survey by the Ministry of Agriculture, Fisheries and Food and the Nuu-chah-nulth Tribal Council for portions of the southwest shore of Nootka Island from Esperanza Inlet to Nootka Sound, the west and south shores of Hesquiat Peninsula and a portion of Hesquiat Harbour. For the first time in B.C., computerized mapping of the kelp resource has been used in combination with traditional inventory methods.

This kelp inventory took place on the 20th anniversary of the first KIM-1 survey of Nootka Sound in 1975 (Coon et al., 1976). In the 20 years that have elapsed, seasonal and annual variation as well as longer-term changes, including the successful reintroduction of sea otters to the west coast of Vancouver Island and large scale oceanic events (El Niño), have affected the local stands of large kelps. The 1995 work has been undertaken to evaluate and document changes in kelp bed extent and composition that have occurred through time and to update stock information for use in treaty negotiations.

Accurate and comprehensive data on the standing crop of kelp in British Columbia provide a basis for allocating these resources through licensing and for establishing area specific harvest quotas. Kelp beds are important to other marine species and kelp inventory charts and data will be of value to those preparing environmental impact statements or conducting surveys for herring spawn, abalone, sea urchins, sea otters and other species.

At the present time, the principal commercial use of large kelp species in B.C. is for herring spawn on kelp. In 1995, 36 licenses to harvest *Macrocystis* were issued and a total of 97.5 tonnes were harvested for this purpose. As well, an additional 8 licenses harvested approximately 10 tonnes of *Nereocystis* and *Macrocystis* for use in the

restaurant trade, in health food stores, for fertilizers, plant sprays and other applications.

METHODS

The KIM-1 technique uses aerial photography in combination with field sampling to produce kelp bed maps and estimates of kelp bed areas and biomass. While the basis of the KIM-1 method has remained the same, certain steps have changed through time to improve accuracy and/or decrease the field work component. Modifications of this method as stated by Coon et al. (1976), Field et al. (1977) and Sutherland (1989 and 1990) were used in this study.

Briefly, the KIM-1 technique involves obtaining 24 cm. format, 1:7,200 scale, black and white, infrared (IR) aerial photography of the kelp bed and shoreline in the desired region. The black and white IR negatives are used to prepare charts of the coastline and the offshore kelp beds. The kelp bed charts produced are divided to sections, or blocks, that are 1 kilometre in width for statistical purposes. Kelp bed area data is derived from the charts.

The technique identifies six bed types on the basis of:

a) species - *Macrocystis* or *Nereocystis* or mixed (considered to be 42% *Nereocystis* and 58% *Macrocystis*; Foreman, 1975); and

b) plant or frond density - low density (less than 10 plants or fronds per 10 square meters) or high (greater than 10 plants or fronds per 10 square meters).

Note: *Macrocystis* density values determined from field transects suggest that the actual density of fronds is higher than predicted by the KIM-1 technique. It follows that the division to high and low density *Macrocystis* beds is at a higher level than 10 fronds per 10 square meters. In the present survey *Macrocystis* density values determined from field transects were applied to all *Macrocystis* areas. High and low density beds have been kept separate on the chartwork and in area measurements,, however, to provide detail as presented in previous inventories.

Near the time that the beds were photographed, field crews obtain samples of kelp from the inventory area for mean weight per plant (*Nereocystis*) or frond *Macrocystis* determination and record numbers of plants along bottom transects to determine density for *Macrocystis*. Density for *Nereocystis* and bed area for both species are determined from mapping and analysis of the aerial photographs. Kelp biomass is

determined by multiplying the mean weight per plant or frond values by the observed or frond densities and multiplying this product by the observed bed areas. All biomass estimates in this report are of total standing crop.

Field sampling took place between August 3 to 7, 1995. Aerial photography was secured on July 29, 1995. The Ministry of Agriculture, Fisheries and Food provided field sampling data and aerial photography of kelp beds under contract to IEC Collaborative Marine Research and Development Ltd. who undertook the initial air photo interpretation and mapping of the kelp beds. The results were provided to McElhanney Consulting Services Ltd., who integrated them on a computer mapping system and generated maps and kelp bed area data. IEC then completed the data analysis for the inventory and produced the present report.

Nereocystis

Prior to work at Porcher Island in 1981 (Coon, 1981), vertical biomass distribution data for *Nereocystis* was used to produce estimates of biomass at various harvesting depths relative to mean water level (MWL). Beginning in 1981, in order to minimize costly field work, the time consuming weighing of each 1 meter increment of *Nereocystis* was not undertaken. In this inventory, wet weight was determined for *Nereocystis* plants as they were sampled at randomly located stations in the survey area. The mean biomass per plant statistic for *Nereocystis* used in subsequent calculations is derived from the mean of sample station means of wet weight per plant.

The density of *Nereocystis* on the surface at the time of photography is determined directly from the photographs with the aid of a microscope and using the KIM-1 point-intercept method (Foreman, 1975). A point-intercept to density regression for *Nereocystis*, as developed by Foreman and Cabot (1979), was employed in this inventory. The tidal heights at the time of photography relate density data from the photos to MWL for further calculations. After 1981, length measurements of *Nereocystis* plants merged relative to MWL were used to produce a table of cumulative numbers of plants in 1 meter increments above and below MWL. These cumulative numbers are used to convert the density observed from the photography to total or bottom density as follows:

Total density at bottom = (Conversion factor) X (Density derived from photography)

Where the conversion factor = $\frac{\text{Total no. plants in all samples}}{\text{no. plants in all samples extending to surface at tidal height at time of photography}}$

Calculations using data from previous inventories (Coon et al., 1977, 1979, 1980, 1981, 1982. Field et al., 1977, 1978) have shown this method, in practice, produces total standing crop estimates differing from those produced using the original KIM-1 method by an average of 2 percent (Sutherland, 1990).

In order to further reduce the field time required for the sampling in the present inventory, measurements to produce vertical profiles were not taken. The correction factor used in the report to convert *Nereocystis* density as visible at the water surface at the time of the flight to total density at the site was taken from the vertical profile for August, 1975 inventory work in the area. While this substitution may introduce error in the overall standing crop estimate, an examination of vertical profiles from past inventories in the August and September period shows limited variation in the portion of plants reaching MWL-1 meter +/- 0.6 meter (the tide at the time of the 1995 photography) and thus in the correction factors (see Table 1).

Table 1. Numbers of plants extending to 1 meter +/- 0.6 meters below Mean Water Level of the total number sampled and expressed as percent for various inventories. The correction factor used in this report to convert *Nereocystis* density at MWL-1 to total density is shown.

Inventory Area:	**Nootka**	Nootka	Dundas	N.Van.I.	Estevan / Campania I.	Goschen I. to Tree Knob	Pt Hardy Malcolm I.	Juan de Fuca
Sample Period:	**end Aug-75**	end Sep-75	Aug-76 exposed	Sep-76	Sep-76	Aug-76	Sep-89	Sep-88
No. Plants @ MWL 1:	**95**	98	123	98	97	72	194	92
Total No. Plants:	**105**	105	127	100	102	77	202	110
% at MWL-1:	**90%***	93%	97%	98%	95%	94%	96%	84%
Correction factor from MWL 1 to total:	**1.1**	1.1	1.0	1.0	1.1	1.1	1.0	1.2

* value used in present report
Correction factor used in the report = 105/95 = 1.1
Overall average % at MWL-1: 93% (for all reports)

Macrocystis

Mean biomass per frond data was collected for *Macrocystis* at randomly located sample stations in the survey area. The mean biomass per frond value reported for *Macrocystis* is also the mean of the sample station means. *Macrocystis* density in this inventory has been determined in the field from counts along underwater transects. In the KIM-1 method, *Macrocystis* density was derived using the point intercept method similar to that presently used for *Nereocystis*. Beginning in 1982, as a result of perceived underestimation of *Macrocystis* biomass by the KIM-1 technique, densities for this species have been estimated from counts by SCUBA divers of the numbers of fronds found within one meter on either side of randomly established 40 meter long transects on the bottom. This provides frond numbers from 80 square meter sections of the bottom at each sample station. The mean density per square meter statistic for *Macrocystis* is derived from the mean of the station means.

Mixed *Nereocystis* and *Macrocystis*

Changes to the method described above have required modification of the method used to calculate mixed bed biomass. Mixed bed biomass per hectare for each kilometer block has been calculated as follows:

Mean biomass per hectare of low or high density mixed kelp	= .42 X	Mean biomass per ha. of low or high *Nereocystis*	+ .58 X	Mean biomass per ha. of *Macrocystis*

The 0.42 and 0.58 figures in the equation are derived from the KIM-1 method. As can be noted, low or high density is not considered for the *Macrocystis* portion of the calculation.

Mapping of Kelp Beds

Although the essentials of the air photo interpretation remain the same, some changes in methods have been necessary to use digitized mapping techniques. An overview of the procedures used in the present inventory is presented below.

While prints of the IR film show land features more clearly and are typically used in mapping, the black and white IR negatives viewed on a standard light table are used in kelp bed interpretation. The dark kelp, especially when in low density beds, stands

out more clearly and with more detail against the light water background in the negative (except where glare and wave action cause darkening and make interpretation difficult or impossible). Also, the use of negatives precludes any loss of clarity that might result during the additional step required for the printing process.

As noted above, the KIM-1 technique identifies six bed types on the basis of species and density. Regarding interpretation and mapping of the kelp beds Foreman (1975) states: "The two species can be distinguished on the negative by a trained observer, although ideally the individuals doing the photographic interpretations should spend some time in the field with the aerial photographs to familiarize themselves with the appearance and location of the two species. *Nereocystis* under magnification has a linear image and, in dense areas, a random stick appearance on the surface of the water. The image is generally quite sharp, as most plants are on the surface. *Macrocystis* has a more clumped image and appears somewhat fuzzy." This is a good description. Problems arise, however, as the physical characteristics of plants, currents, weather at the time of photography and the presence of other macrophytes in shallow water tend to vary somewhat with time and from area to area and can make the distinction between species less clear. Foreman recognizes the problem and goes on to state: "Field surveys should locate bed types on charts, whenever possible, for use by the interpreter." Notes made during field biomass sampling and sampling site locations can help to confirm interpretations during inventory work. Such information was used during the present inventory whenever possible. Kelp beds are denoted as mixed when the two species occur intermixed such that they cannot be efficiently separated during interpretation.

The high and low density separation at 10 plants or fronds per 10 square meters is arbitrary and has been used in all inventories in British Columbia to date. Its purpose is to allow increased accuracy of density estimates based on the photography (for *Nereocystis* in recent inventories) by dividing the random samples for the point intercept method (Foreman, 1975) to more similar groupings of high and low density bed types. In the present inventory, *Macrocystis* beds were divided to high and low density on maps based on point intercept methods as in previous inventories to maintain consistency and to allow comparisons.

From the negatives, maps outlining the kelp beds and including geographic features such as the edge of terrestrial vegetation and tide height on shore at the time were drawn on clear mylar film overlays. Colour and line-type coding were used to

separate the bed types and geographic features. These overlays were found to be compatible with the digitizing activities used in the present inventory provided:

- one overlay sheet of mylar film was used per frame;
- the overlay positioning was related to frames by marking the positions of
- feducials from each frame on corresponding overlays (feducials are reference marks on frames); and
- the frame number was noted in the same corner of the overlay as it appears on the frame for identification and to confirm proper orientation of the overlay.

McElhanney Consulting Services Ltd. were contracted to digitize the polygons provided on the mylar sheets and the shoreline from aerial photographs using monorestitution techniques. The company also placed the statistical kilometre blocks, calculated the areas of kelp bed polygons, provided computer data files (ARCINFO spatial data set) and 1:20,000 scale maps very similar in format to those used in previous kelp inventory reports.

RESULTS

Kelp bed area for all bed types and density estimates for *Nereocystis* provided in this report are based on the aerial photography for the inventory area which was flown July 29, 1995 between 10:17 AM and 11:00 AM local time (Pacific Daylight Saving Time). This places the timing of the photography within the desired 10:00 AM to 2:00 PM range that provides proper sun angles for adequate picture quality.

Tidal data and correction factors were provided by the Canadian Hydrographic Service, Institute of Ocean Sciences. The tidal gauge at Tofino, the closest recorder to the Nootka Sound area, was not in service at the time of inventory work. As recommended by the Service, readings from the tidal gauge at Bamfield were corrected to Tofino and subsequently to Saavedra Island, Nootka Sound, the tidal station for the survey area. Required corrections were quite small. Tidal height at the time of photography was within the MWL minus 1 meter +/- 0.6 meter KIM-1 tidal range.

Winds and waves at the time of photography were rising. Two foot seas reported in the area at 07:00 AM reached six foot moderate seas by 2:00 PM with winds to NW 35 knots. A low SW swell was also present (Climat Services, telephone communication). The combination of winds, waves and sun angle resulted in glare on

some photographs and rendered portions of the film unusable. Unusable sections were not mapped during photo interpretation.

Chart Sheets 1 through 5 (Appendix) illustrate the disposition of kelp bed resources by bed type along the inventory area (Figure 1). The numbering and placement of the kilometer wide statistical blocks have changed from the 1975 inventory layout due to differing photographic coverage and to more accurate mapping and measurement procedures used in positioning of blocks.

Table 2 presents the field-determined mean biomass per plant (wet weight) estimates obtained from means of twelve *Nereocystis* and eighteen *Macrocystis* sampling stations in the inventory area. A total of 124 *Nereocystis* plants and 457 *Macrocystis* fronds were sampled at these stations August 3 to 7, 1995. The *Macrocystis* density value derived from transect counts performed on the same dates and at the same locations as *Macrocystis* biomass samples were taken (with the exception of 1 station where biomass sampling was not done) is shown in Table 3. As can be seen from the standard deviation (SD) values reported, considerable variability exists between stations. Maximum and minimum station mean biomass values were 7.3 and 0.7 kg. per *Nereocystis* plant and 2.3 and 0.4 kg. per *Macrocystis* frond. Maximum and minimum *Macrocystis* mean station densities from transects were 29.2 and 1.6 fronds per square meter. High densities found in the area are supported by the presence of uniform rocky substrate for secure holdfast attachment (M. Coon, pers. comm.).

Tables 4 through 8 present estimates of kelp bed areas, density and biomass for each block in Chart Sheets 1 through 5. Table 9 summarizes the data for the entire area. Tables 10, 11 and 12 summarize the bed area and biomass estimates, the percent biomass and the percent bed area composition, respectively, for each bed type in each chart area.

Table 2. *Nereocystis* mean biomass per plant and *Macrocystis* mean biomass per frond estimates from August 3, 4, 5, 6 and 7, 1995 field samples as used to calculate biomass estimates for the inventory area.

Nereocystis mean biomass/plant = 4.7 kg. 12 stations SD = 2.1
Macrocystis mean biomass/frond = 1.1 kg. 18 stations SD = 0.5

Table 3. Field determined *Macrocystis* density value from August 3, 4, 5, 6 and 7, 1995 transect samples used in total standing crop estimates for the inventory area.

Mean number of fronds per square meter of *Macrocystis* bed	= 9.7	19 stations	SD = 6.3

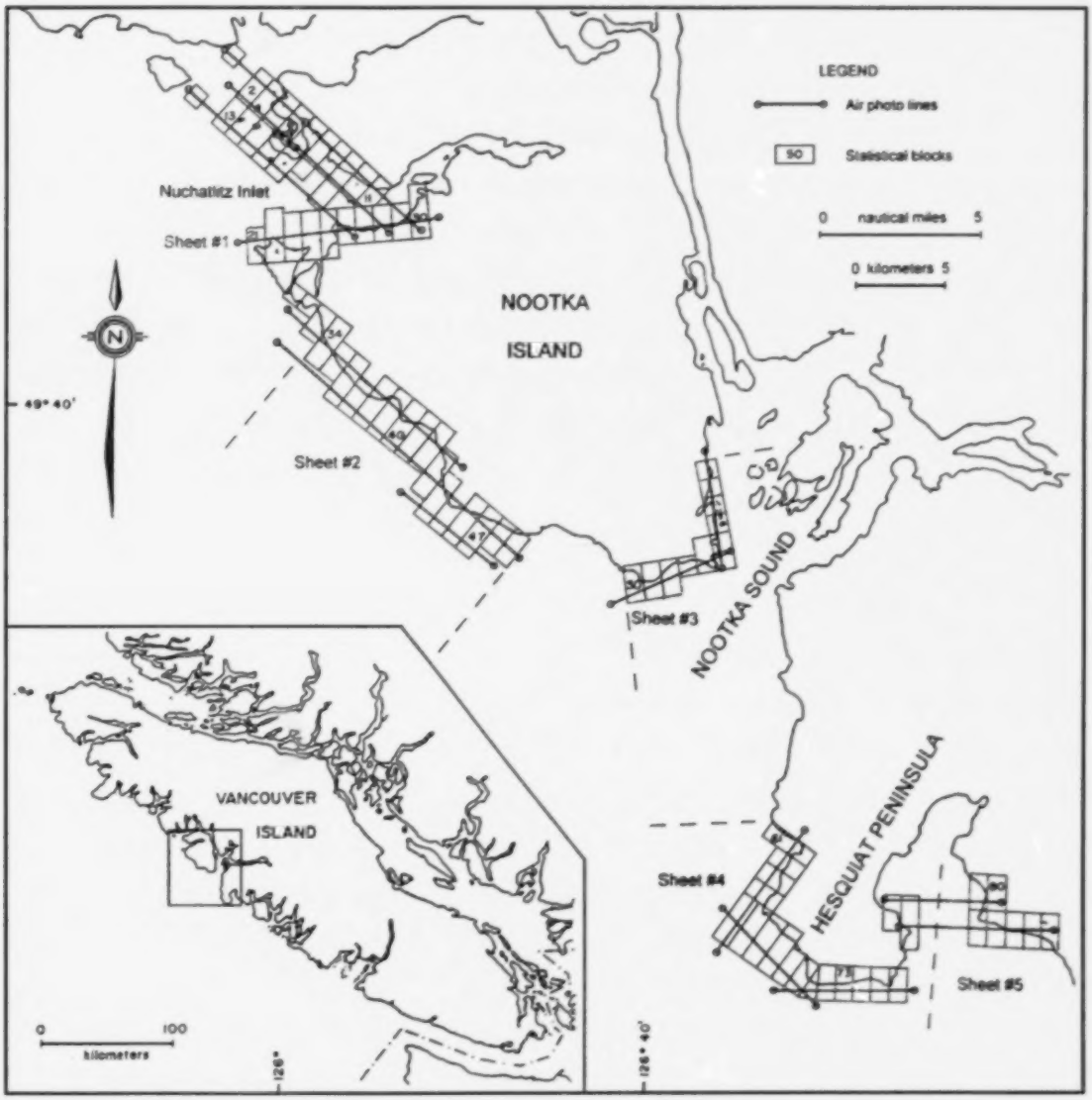

Figure 1. Map of the Nootka Sound inventory area for 1995 showing the layout of statistical blocks and air photo flight lines.

Table 4. Estimates of kelp bed area and biomass for Nuchatlitz Inlet entrance. July/August, 1995. See Sheet 1 (appendix).
B = Biomass (metric tonnes) ha = hectare D = Density (no. of plants or fronds/hectare)

SHEET 1	Nereocystis Low Density					Nereocystis - High Density					Macrocystis						Mixed - Low Density			Mixed - High Density			Total	Total
												Low D	High D	Total										
Rock	Photo Mean D	Bottom Mean D	Area (ha)	Mean B/ha	B	Photo Mean D	Bottom Mean D	Area (ha)	Mean B/ha	B	Bottom Mean D	Area (ha)	Area (ha)	Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	B
1											97,000	2.15	1.64	3.79	106.7	404.5							3.79	404.5
2						21,600	24,000	0.57	111.8	63.8							1.86	72.7	135.2	1.26	107.2	135.0	3.69	333.9
3											97,000	0.96	2.47	3.43	106.7	365.8	5.20	72.7	378.2	1.86	107.2	199.1	10.49	943.1
4																								
5																								
6											97,000	0.01		0.01	106.7	1.5							0.01	1.5
7											97,000	1.63		1.63	106.7	174.4							1.63	174.4
8											97,000	0.10		0.10	106.7	10.3							0.10	10.3
9											97,000	0.07		0.07	106.7	7.3							0.07	7.3
10																								
11																								
12	5,800	6,400	4.83	29.8	144.1	21,600	24,000	1.51	111.8	169.4													6.35	313.5
13	6,200	6,800	2.73	31.7	86.5						97,000	5.54	0.89	6.43	106.7	685.6	1.77	73.5	130.1				1 '93	902.3
14	5,900	6,500	5.62	30.3	170.4						97,000	13.80	8.69	22.50	106.7	2,400.5	6.77	72.9	493.9	0.40	107.2	42.5	350.49	3,113.1
15	5,400	5,900	5.49	27.5	151.1						97,000	16.39	9.70	26.10	106.7	2,784.4	6.29	71.8	451.3	0.12	107.2	12.7	38'00	3,399.5
16											97,000	9.70	3.00	12.70	106.7	1,354.8	0.67	72.5	48.9	0.83	107.2	89.0	14.20	1,492.6
17	5,700	6,300	0.15	29.4	4.4						97,000	7.42	2.58	9.98	106.7	1,064.4							10.13	1,068.8
18											97,000	6.45	1.45	7.90	106.7	843.1							7.90	843.1
19																								
20																								
21	6,300	6,900	5.86	32.2	188.6	21,600	24,000	0.31	111.8	34.2							0.80	73.7	59.2				6.97	282.0
22	6,300	6,900	3.71	32.2	119.2	21,600	24,000	0.22	111.8	24.4	97,000	1.34	0.77	2.11	106.7	225.1	1.69	73.7	124.8	0.42	107.2	44.7	8.14	537.9
23	6,600	7,300	0.93	34.0	30.8						97,000	8.55	2.06	7.61	106.7	811.9	0.59	74.5	44.0				9.11	886.7
24	6,600	7,300	0.54	34.0	18.5						97,000	3.47	0.42	3.89	106.7	415.2	1.08	74.5	80.8				5.52	514.5
25	6,600	7,300	0.45	34.0	15.4						97,000	0.25		0.25	106.7	26.2							0.70	41.6
26	6,600	7,300	0.08	34.0	2.8						97,000	0.47	0.08	0.55	106.7	59.1							0.63	61.7
27																								
28																								
29																								
30																								
31																								
32																								
33																								
ds. 1-33 Totals:			30.58		937.6			2.61		291.8		75.31	33.73	109.04		11,634.2	28.73		1,948.2	4.88		522.7	173.64	15,332.5

Table 5. Estimates of kelp bed area and biomass for the southwest side of Nootka Island. July/August, 1995. See Sheet 2 (appendix).
B = Biomass (metric tonnes) ha = hectare D = Density (no. of plants or fronds/hectare)

SHEET 2	Nereocystis Low Density					Nereocystis - High Density					Macrocystis						Mixed - Low Density			Mixed - High Density			Total	Total
											Low D	High D	Total											
Block	Photo. Mean D	Bottom Mean D	Area (ha)	Mean B/ha	B	Photo. Mean D	Bottom Mean D	Area (ha)	Mean B/ha	B	Bottom Mean D	Area (ha)	Area (ha)	Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	B
34	4,700	5,200	2.58	24.2	62.1						97,000	0.94	0.29	1.23	106.7	131.4							3.79	193.5
35	4,700	5,200	1.95	24.2	47.1						97,000	1.67	2.04	3.70	106.7	395.1	1.75	70.4	123.4				7.40	565.7
36	4,900	5,400	4.80	25.2	120.7						97,000	6.34	4.80	11.14	106.7	1,188.8	0.36	70.8	25.7				6.30	1,335.2
37	5,100	5,600	1.82	26.1	47.5						97,000	3.52	7.05	10.57	106.7	1,127.9	0.93	71.2	66.0				13.32	1,241.4
38											97,000	6.84	18.03	24.77	106.7	2,643.1							24.77	2,643.1
39											97,000	9.85	10.20	20.06	106.7	2,140.1							20.06	2,140.1
40	5,000	5,500	0.47	25.6	12.0						97,000	2.57	3.89	6.46	106.7	689.1							6.93	701.1
41											97,000	9.10	3.62	12.71	106.7	1,356.5							12.71	1,356.5
42											97,000	1.88	1.31	2.99	106.7	319.2							2.99	319.2
43											97,000	7.02	7.78	14.80	106.7	1,578.8							14.80	1,578.8
44	5,400	5,900	0.62	27.5	17.0						97,000	16.19	12.30	28.49	106.7	3,039.9							29.11	3,056.9
45	5,400	5,900	1.47	27.5	40.3						97,000	4.27	8.81	13.08	106.7	1,395.1	3.86	71.8	219.8	0.13	106.6	13.6	17.73	1,668.8
46	5,700	6,300	1.32	29.4	38.7						97,000	16.80	12.98	29.58	106.7	3,156.8	0.51	72.5	37.2				31.41	3,232.4
47											97,000	3.67	7.22	10.89	106.7	1,161.5							10.89	1,161.5
48											97,000	7.73	7.46	15.19	106.7	1,620.8							15.19	1,620.8
49											97,000	11.44	1.80	13.24	106.7	1,412.4							13.24	1,412.4
Blks. 34-49 Totals:			15.00		385.5			0.00		0.0		108.42	110.47	218.89		23,356.0	6.62		472.2	0.13		13.6	240.64	24,227.2

Table 6. Estimates of kelp bed area and biomass for southeast Nootka Island. July/August, 1995. See Sheet 3 (appendix).
B = Biomass (metric tonnes) ha = hectare D = Density (no. of plants or fronds/hectare)

SHEET 3	Nereocystis Low Density					Nereocystis - High Density					Macrocystis						Mixed - Low Density			Mixed - High Density			Total	Total
											Low D	High D	Total											
Block	Photo. Mean D	Bottom Mean D	Area (ha)	Mean B/ha	B	Photo. Mean D	Bottom Mean D	Area (ha)	Mean B/ha	B	Bottom Mean D	Area (ha)	Area (ha)	Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	B
50	7,100	7,800	0.34	36.3	12.5	21,500	23,700	0.04	119.4	4.3						0.0							3.8	16.7
51	7,100	7,800	3.36	36.3	122.0	21,500	23,700	0.09	119.4	10.4	97,000	0.12		0.12	106.7	12.3	0.58	75.5	43.5				4.14	188.1
52	7,100	7,800	0.04	36.3	1.6						97,000	0.04		0.04	106.7	4.4							0.08	6.0
53											97,000	0.30	0.06	0.36	106.7	38.3							0.36	38.3
54											97,000	0.33	0.01	0.34	106.7	36.1							0.34	36.1
55											97,000	0.71	0.01	0.72	106.7	76.9							0.72	76.9
56											97,000	1.22		1.22	106.7	130.6							1.22	130.6
57											97,000	1.28		1.28	106.7	136.1							1.28	136.1
58	7,100	7,800	0.07	36.3	2.7						97,000	0.03		0.03	106.7	3.6							0.11	6.2
59																0.0								
60																0.0								
Blks. 50-60 Totals:			3.82		138.7			0.13		14.8		4.02	0.08	4.11		439.0	0.58		43.5	0.00		0.0	8.83	634.81

Table 7. Estimates of kelp bed area and biomass for Hesquiat Peninsula. July/August, 1995. See Sheet 4 (appendix).
B = Biomass (metric tonnes) ha = hectare D = Density (no. of plants or fronds/hectare)

SHEET 4	Nereocystis Low Density					Nereocystis - High Density					Macrocystis						Mixed - Low Density			Mixed - High Density			Total	Total
												Low D	High D	Total										
Block	Photo. Mean D	Bottom Mean D	Area (ha)	Mean B/ha	B	Photo. Mean D	Bottom Mean D	Area (ha)	Mean B/ha	B	Bottom Mean D	Area (ha)	Area (ha)	Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	B
61	7,400	8,100	2.46	37.7	92.7											0.0							2.46	92.7
62	7,200	7,900	9.08	36.8	334.3	21,500	23,700	1.47	110.4	162.4	97,000	0.09	0.12	0.21	106.7	22.3							10.76	519.1
63	7,200	8,400	35.66	39.1	1,403.6	21,500	23,700	4.43	110.4	489.2	97,000	1.92	2.51	4.42	106.7	472.1							44.72	2,365.2
64	7,300	8,000	21.22	37.3	790.9	20,300	22,300	1.68	103.0	172.3	97,000	0.25	0.12	0.37	106.7	39.9							23.25	1,003.2
65	6,500	7,200	31.56	33.6	1,059.6	28,200	31,000	11.65	144.5	1,682.9	97,000	0.45	0.08	0.53	106.7	56.6	4.50	74.3	341.8				48.36	3,140.9
66	6,200	9,000	6.20	41.9	259.9	26,300	28,900	1.25	134.7	166.5	97,000	8.82	21.45	30.27	106.7	3,230.3	7.81	77.8	607.5	1.01	116.8	117.6	48.63	4,387.8
67	6,100	8,000	1.12	41.5	46.6	23,900	28,500	0.18	132.8	24.3	97,000	7.78	13.90	21.68	106.7	2,313.0	1.21	77.8	93.7				24.19	2,477.7
68	6,100	8,000	0.30	41.5	12.4						97,000	5.78	4.29	10.07	106.7	1,074.1							10.37	1,086.5
69	6,400	7,000	0.74	32.6	24.0						97,000	5.41	4.76	10.17	106.7	1,085.4							10.91	1,109.4
70	6,700	7,400	5.45	34.5	187.8	18,400	20,200	0.17	94.1	15.9	97,000	1.72	5.30	7.02	106.7	749.3	2.66	74.7	199.4	0.27	99.7	27.4	15.46	1,179.8
71	6,500	7,200	6.72	33.6	225.6	18,400	20,200	0.07	94.1	6.9	97,000	2.88	2.01	4.89	106.7	521.3	3.74	74.3	277.7	0.32	99.7	32.0	15.74	1,063.6
72	5,500	6,100	1.01	28.4	28.8	18,400	20,200	0.08	94.1	7.4	97,000		1.31	1.31	106.7	139.8	18.68	72.1	1,347.7	0.88	99.7	87.7	21.98	1,611.3
73	5,300	5,800	3.76	27.0	101.6						97,000	2.93	6.17	9.10	106.7	970.9	12.58	71.8	907.8	1.02	99.7	101.7	26.56	2,081.6
74	6,100	6,700	2.69	31.2	83.9	18,400	20,200	0.13	94.1	12.0	97,000	7.62	16.42	24.04	106.7	2,565.1	7.77	73.3	569.6				34.62	3,230.5
75	6,300	6,900	7.25	32.2	233.2	18,400	20,200	0.31	94.1	29.5	97,000	4.76	4.12	8.88	106.7	947.4	1.31	73.7	96.6	0.17	99.7	16.6	17.92	1,323.3
76	6,100	6,700	4.03	31.2	126.0	18,400	20,200	0.60	94.1	56.7	97,000	0.91	1.38	2.29	106.7	244.1	13.31	73.3	976.0	1.52	99.7	151.4	21.75	1,554.1
77																0.0								
78																0.0								
Blks. 61-78 Totals			139.56		5,015.0			22.01		2,827.9		51.32	83.94	135.25		14,431.7	73.66		5,408.7	5.19		534.3	379.99	28,217.7

Table 8. Estimates of kelp bed area and biomass for the Hesquiat Point area. July/August, 1995. See Sheet 5 (appendix).
B = Biomass (metric tonnes) ha = hectare D = Density (no. of plants or fronds/hectare)

SHEET 5	Nereocystis Low Density					Nereocystis - High Density					Macrocystis						Mixed - Low Density			Mixed - High Density			Total	Total
												Low D	High D	Total										
Block	Photo. Mean D	Bottom Mean D	Area (ha)	Mean B/ha	B	Photo. Mean D	Bottom Mean D	Area (ha)	Mean B/ha	B	Bottom Mean D	Area (ha)	Area (ha)	Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	B
79											97,000	3.96		3.96	106.7	422.6							3.69	422.6
80																0.0								
81											97,000	14.25	12.03	26.29	106.7	2,804.6							26.29	2,804.6
82											97,000	7.82	0.31	8.13	106.7	867.4							8.13	867.4
83											97,000	8.97	0.68	9.65	106.7	1,050.7							9.65	1,050.7
84											97,000	2.52	0.09	2.61	106.7	278.7							2.61	278.7
85																0.0								
Blks. 79-85 Totals			0.00		0.0			0.00		0.0		37.53	13.31			5,424.0	0.00		0.0	0.00		0.0	50.83	5,424.0

Table 9. Estimates of kelp bed area and biomass for the entire Nootka Sound inventory area. July/August, 1995.
B = Biomass (metric tonnes) ha = hectare

	Nereocystis Low Density		Nereocystis - High Density		Macrocystis				Mixed - Low Density		Mixed - High Density		Total	Total
					Low D	High D	Total							
	Area (ha)	B	Area (ha)	B	Area (ha)	Area (ha)	Area (ha)	B	Area (ha)	B	Area (ha)	B	Area (ha)	B
Total Blocks 1-85	166.95	6,478.8	24.75	3,134.3	276.60	241.53	518.13	55,263.9	107.99	7,870.48	10.19	1,070.7	849.80	73,836.2

Table 10: Summary of total standing crop biomass and kelp bed area estimates by chart area (see Figure 1) and bed type for the 1995 Nootka Sound inventory area.

Chart	Geographic area	Biomass (tonnes)	Area (ha.)
	Low Density *Nereocystis*		
Sheet 1	Nuchatlitz Inlet entrance.	937.6	30.6
Sheet 2	Southwest side of Nootka I.	385.5	15.0
Sheet 3	Southeast part of Nootka I.	138.7	3.8
Sheet 4	Hesquiat Peninsula	5,015.0	139.6
Sheet 5	Hesquiat Point	0.0	0.0
	High Density *Nereocystis*		
Sheet 1	Nuchatlitz Inlet entrance	291.8	2.6
Sheet 2	Southwest side of Nootka I.	0.0	0.0
Sheet 3	Southeast part of Nootka I.	14.6	0.1
Sheet 4	Hesquiat Peninsula	2,827.9	22.0
Sheet 5	Hesquiat Point	0.0	0.0
	Low and High Density *Macrocystis*		
Sheet 1	Nuchatlitz Inlet entrance	11,634.2	109.0
Sheet 2	Southwest side of Nootka I.	23,356.0	218.9
Sheet 3	Southeast part of Nootka I.	438.0	4.1
Sheet 4	Hesquiat Peninsula	14,431.7	135.3
Sheet 5	Hesquiat Point	5,424.0	50.8
	Low Density Mixed		
Sheet 1	Nuchatlitz Inlet entrance	1,946.2	26.7
Sheet 2	Southwest side of Nootka I.	472.2	6.6
Sheet 3	Southeast part of Nootka I.	43.5	0.6
Sheet 4	Hesquiat Peninsula	5,408.7	73.7
Sheet 5	Hesquiat Point	0.0	0.0
	High Density Mixed		
Sheet 1	Nuchatlitz Inlet entrance	522.7	4.9
Sheet 2	Southwest side of Nootka I.	13.6	0.1
Sheet 3	Southeast part of Nootka I.	0.0	0.0
Sheet 4	Hesquiat Peninsula	534.3	5.2
Sheet 5	Hesquiat Point	0.0	0.0

Totals by species:	*Nereocystis*	9,611.1	213.7
	Macrocystis	55,283.9	518.1
	Mixed	8,941.2	117.8
Totals by chart area:	Sheet 1	15,332.5	173.8
	Sheet 2	24,227.3	240.6
	Sheet 3	634.8	8.6
	Sheet 4	28,217.6	375.7
	Sheet 5	5,424.0	50.8
Total of all species for entire inventory area:		73,836.2	849.6

Table 11. Percent composition of low and high density *Nereocystis*, *Macrocystis* and mixed bed total biomass in each chart area. The last column gives percent composition of the total biomass for the entire 1995 Nootka Sound Inventory area.

Chart Sheet:	1	2	3	4	5	Combined
Nereocystis						
-low density	6.1%	1.6%	21.8%	17.8%	0.0%	8.8%
-high density	1.9%	0.0%	2.3%	10.1%	0.0%	4.2%
Macrocystis						
-high and low	75.9%	96.4%	69.0%	51.1%	100.0%	74.9%
Mixed						
-low density	12.7%	1.9%	6.9%	19.2%	0.0%	10.7%
-high density	3.4%	0.1%	0.0%	1.9%	0.0%	1.4%

Table 12. Percent composition of low and high density *Nereocystis*, *Macrocystis* and mixed bed estimates of surface area in each chart area. The last column gives percent composition of bed area for the entire 1995 Nootka Sound area.

Chart Sheet:	1	2	3	4	5	Combined
Nereocystis						
-low density	17.6%	6.2%	44.2%	37.1%	0.0%	22.2%
-high density	1.5%	0.0%	1.5%	5.9%	0.0%	2.9%
Macrocystis						
-high and low	62.7%	91.0%	47.6%	36.0%	100.0%	61.0%
Mixed						
-low density	15.4%	2.8%	6.7%	19.6%	0.0%	12.7%
-high density	2.8%	0.1%	0.0%	1.4%	0.0%	1.2%

DISCUSSION

A total of 9,611 tonnes of *Nereocystis*. 55,284 tonnes of *Macrocystis* and 8,941 tonnes of mixed kelp were estimated to lie within the 85 kilometre-wide blocks inventoried. Over the entire inventory area, 518.1 hectares of *Macrocystis* bed made up 61% of the kelp bed area, 213.7 hectares of *Nereocystis* made up 25.1%, and 117.8 hectares of mixed bed made up the remaining 13.9%. The very high mean density found for *Macrocystis* in field surveys resulted in that species making up 74.9% of the total biomass in the inventory area; *Nereocystis* made up 13.0% while mixed kelp made up 12.1% of the total.

The major concentrations of kelp found within the surveyed area were distributed along the southwest shore of Nootka Island (Sheet 2, Table 5) and along the Hesquiat Peninsula (Sheet 4, Table 7). Chart Sheet 1 at the entrance of Nuchatlitz Inlet contains a complex of islands, mainly with small fringing beds but with moderate quantities in blocks 14 and 15. Sheet 3 at the southern end of Nootka Island contains only small, fringing beds. The small area covered by Sheet 5 contains a concentration of *Macrocystis* off Hesquiat Point.

Macrocystis beds covered by the survey had a mean total biomass of 10.7 kg. per square meter. Over the entire inventory area, low density *Nereocystis* beds averaged 3.4 kg., high density *Nereocystis* beds averaged 12.7 kg., low density mixed beds averaged 7.3 kg. and high density mixed beds averaged 10.5 kg. per square meter.

Macrocystis made up most of the estimated biomass for all areas and more of the bed area for Sheets 1, 2, 3 and 5 (Sheet 5 contained only *Macrocystis*) than either *Nereocystis* or mixed beds (although Sheet 3 contained almost as much *Nereocystis* bed area). The region covered by Chart Sheet 4 contained more *Nereocystis* bed area.

The largest *Nereocystis* beds were found in Sheet 4 off the west shore of the Hesquiat Peninsula in Blocks 63 to 65. The largest *Macrocystis* bed areas were found in: Blocks 14 and 15 in Sheet 1; Blocks 38, 39, 44 and 46 in Sheet 2; Blocks 66, 67 and 74 in Sheet 4; and Block 81 in Sheet 5. Mixed beds were not as extensive; most were found in Sheet 4.

Of the total combined standing crop of 73,836 tonnes, 41.7% (or 30,7782 tonnes) are not available for commercial harvest because the beds are located within protected areas designated in the 1993 Clayoquot Sound Land Use Decision.

Comparison With Kelp Inventory 1975, Nootka Sound

The following section compares areas covered by both 1975 and 1995 inventories and examines changes in bed area and estimated total standing crop biomass. No comparison was made with earlier estimates made for the area by Huff (1967). A discussion of Huff's estimates, the methods used and differences from 1975 estimates can be found in Coon et al. (1976).

In comparing the results of the two inventories, it is important to keep in mind the changes to methodologies and manner of reporting the data that have taken place. When good aerial photographic coverage is available, kelp bed area determination can be quite exacting. Methods used for measuring area have taken advantage of new technologies but in general the process has changed little. Mean biomass per plant or frond and density estimation have both undergone changes. Both are used in combination with bed area to estimate kelp biomass.

In the 1975 inventory work for Nootka Sound (Coon et al., 1976), results were ported as biomass above mean water level, as well as total standing crop (see table 1.9 Coon et al. (1976)). Changes to techniques noted in the method, and the requirement for total standing crop information for harvest quota determination have resulted in the reporting of total standing crop biomass. Total standing crop biomass is always higher than the biomass above mean water level for these species and care should be used when comparing estimates from past inventory work. In this comparison, 1975 values have been converted to total standing crop biomass.

Mean biomass per plant and density methodologies have changed significantly since the 1975 inventory. The *Macrocystis* density values derived from the underwater transect counts are known to be higher than those that result when KIM-1 density methods are used as was the case in 1975. This higher density in turn results in a higher biomass per hectare estimate.

Average total biomass per hectare of high or low density *Macrocystis* in 1995 is estimated at 106.7 tonnes while the maximum biomass per hectare in late August, 1975 for high and low density begins was 39.5 tonnes and 15.2 tonnes, respectively (1975 values converted to total biomass; overall average values of biomass per hectare for *Macrocystis* in 1975 would be lower than these maximum values). The mean total biomass per plant for *Nereocystis* and frond for *Macrocystis* were both higher in 1975 than in 1995 as shown in Table 13.

Table 13. The mean total biomass per plant is presented for both the 1975 and 1995 inventories. Data for the 1975 inventory has been converted to total biomass by using the reported conversion factors.

Sample Date	*Nereocystis*	*Macrocystis*
July/August, 1975	5.0	2.0
Early August, 1995	4.7	1.1

While the statistical kilometre block layouts are not equivalent for 1975 and 1995 surveys, two areas covered in both years are generally comparable. Kelp contained within Blocks 33 to 49 (Area A - on the southwest coast of Nootka Island) and 61 to 76 (Area B on the Hesquiat Peninsula) of the 1995 inventory can be compared with that in Blocks 1 to 16 and 43 to 56, respectively, of the 1975 inventory.

As summarized in Table 14, between 1975 and 1995 both areas have shown declines in *Nereocystis* and mixed bed areas while *Macrocystis* bed areas have remained relatively constant. Table 15 shows the declines in *Nereocystis* and mixed bed biomass resulting from the decreased bed area. An increase in *Macrocystis* biomass result of higher density in 1995. Figures 2 and 3 show the changes graphically by area. Overall, in 1995 Areas A and B have shown decreases in total kelp bed area but an increase in total kelp biomass. The increase in biomass indicates that the higher density estimated for 1995 over-rides the lower mean biomass per frond for *Macrocystis* as well as the lower *Nereocystis* and mixed bed areas and biomass reported for that year.

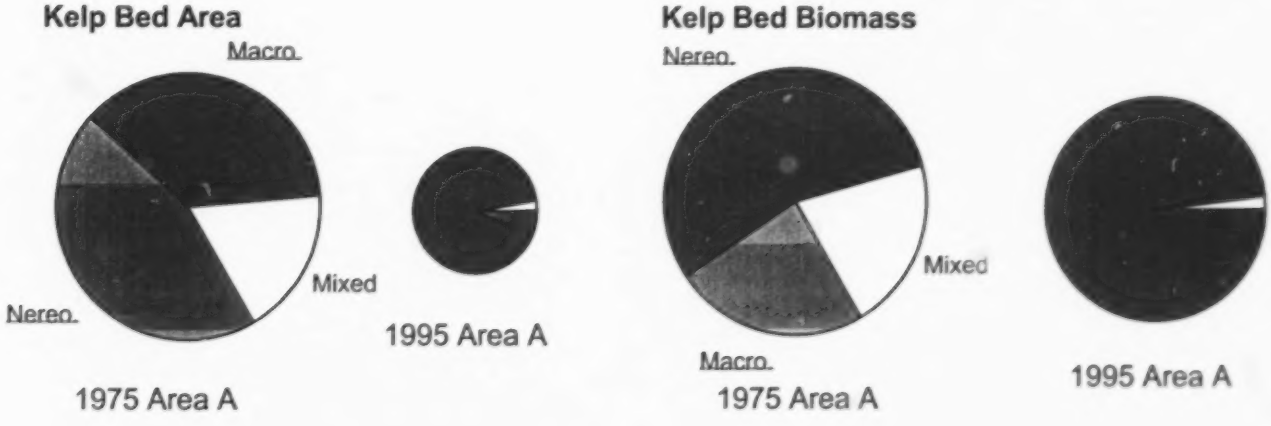

Figure 2. Pie charts show changes in bed area and biomass by species for Area A. Area charts are proportional in size as are biomass charts.

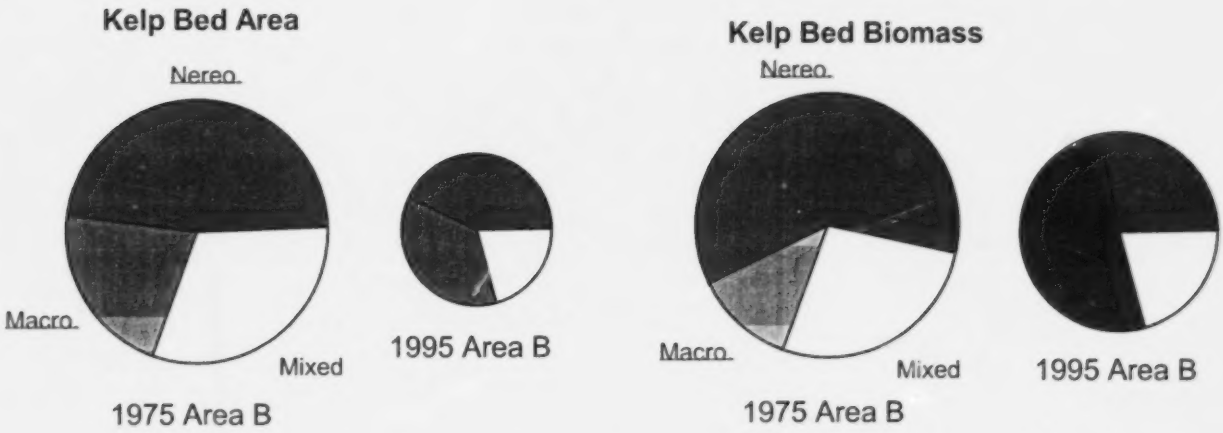

Figure 3. Pie charts show changes in bed area and biomass by species for Area B. Area charts are proportional in size as are biomass charts.

Table 14. Kelp bed areas (hectares) of similar segments of coastline for 1975 and 1995 in the Nootka Sound inventory area. (1975 data adapted from Coon, et al., 1976; high and low denote density; n = *Nereocystis*; m = *Macrocystis*; mix = mixed beds; Change shows increase or decline, "+" value indicates increase between 1975 and 1995, "-" value indicates decrease).

Area A - off the southwest coast of Nootka Island (hectares)

	high n	low n	high m	low m	high mix	low mix	total
1995#33-49	0.00	15.00	110.47	108.42	0.13	6.62	240.64
1975#1-16	68.90	184.29	132.35	75.48	47.02	53.86	561.90
Change:	-68.90	-169.30	-21.88	32.94	-46.89	-47.24	-321.26

	n	m	mix	total
1995#33-49	15.00	218.89	6.75	240.64
1975#1-16	253.19	207.83	100.88	561.90
Change:	-238.19	11.07	-94.13	-321.26

Area B - off the Hesquiat Peninsula (hectares)

	high n	low n	high m	low m	high mix	low mix	total
1995#61-76	22.01	139.56	83.94	51.32	5.19	73.66	375.66
1975#43-56	88.13	228.62	73.67	69.67	64.64	142.03	666.75
Change:	-66.12	-89.06	10.27	-18.35	-59.46	-68.37	-291.09

	n	m	mix	total
1995#61-76	161.56	135.25	78.84	375.66
1975#43-56	316.74	143.34	206.67	666.75
Change:	-155.18	-8.08	-127.83	-291.09

Table 15. Total kelp bed biomass (tonnes) of similar segments of coastline for 1975 and 1995 in the Nootka Sound inventory area. (1975 data adapted from Coon, et al, 1976; correction factors used to change values to total standing crop; high and low denote density; n = *Nereocystis*; m = *Macrocystis*; mix - mixed beds; Change shows increase or decline, "+' value indicates increase between 1975 and 1995, "-" value indicates decrease).

Area A - off the southwest coast of Nootka Island (tonnes)

	high n	low n	m	high mix	low mix	total
1995#33-49	0	385	23,356	14	472	24,228
1975#1-16	5,912	4,865	4,699	3,192	956	19,624
Change:	-5,912	-4,479	18,657	-3,178	-484	4,603

	n	m	mix	total
1995#33-49	385	23,356	486	24,228
1975#1-16	10,777	4,699	4,149	19,624
Change:	-10,391	18,657	-3,663	4,603

Area B - off Hesquiat Peninsula (tonnes)

	high n	low n	high m	low m	high mix	low mix	total
1995#61-76	2,828	5,015	8,956	5,476	534	5,409	28,218
1975#43-56	7,377	6,799	2,079	773	4,452	1,883	23,363
Change:	-4,549	-1,784	6,877	4,703	-3,917	3,526	4,855

	n	m	mix	total
1995#61-76	7,843	14,432	5,943	28,218
1975#43-56	14,176	2,852	6,335	23,363
Change:	-6,333	11,580	-392	4,855

In Area A, only remnants of large *Nereocystis* beds present off the Skuna Bay and Bajo Point region in 1975 were found in 1995. In 1975 there were also extensive beds on Inner and Outer Bajo Reefs totalling over 538 hectares and estimated to contain over 31,000 tonnes of kelp (total standing crop, adapted from Coon et al., 1976), 95% of which was *Nereocystis*. While only a small part of these extensive reef areas was covered by the 1995 photography, in those areas that were included (parts of the inner reef in Blocks 45 and 46), only small *Macrocystis* beds were noted. The decline of the Bajo Reef beds was also noted by the field sampling crew. Dives during 1995 at the location of 1975 beds revealed extensive non-floating perennial macrophyte beds and no live sea urchins (M. Coon, pers. comm.). While Area B, several miles to the south and including the waters off the Hesquiat Peninsula, shows a general decline in the extent of outer *Nereocystis* beds between the 1975 and 1995 surveys, some large beds remain. These changes may be related to the reintroduction of sea otters in the area during the late 1970's.

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APPENDIX

Charts on Sheets 1 through 5 are enclosed in the following envelope in reduced format.
Charts at 1:20,000 scale are available by special request from the Ministry.

MAPS

NOT FILMED

CARTES

NON FILMÉ

Micromedia
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